

Easy to Use, but Hard to Find:
Biodiesel, and its Role in Greening the Udall Legacy Bus Tour

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PURPOSE

When the Udall Legacy Bus Tour started in June, everyone was very excited about running the motor coach across the country on 20% biodiesel, known in the industry as “B20”. While the enthusiasm was great, I quickly realized that much confusion existed among the riders and folks we met along our journey about our fuel and the engine. At every stop people were curious and impressed that we were using biodiesel in the bus, but almost half of our discussions entailed clearing up misconceptions about what biodiesel is and how it can be used. Thus, because I hope everybody we touched along our journey will make an educated attempt to green their travels, I’d like to ensure the readers are somewhat familiar with biodiesel (without repeating too much information that is easily found online). After giving a quick overview of what biodiesel and B20 are (and are not), I will summarize our logistical experience finding B20, and will attempt to compare the economic and environmental implications of using B20 to other realistic alternatives.

CLEARING UP THE CON-FUEL-SION

While our engine is an impressively clean-burning 2007 Caterpillar diesel engine, it was not set up to burn pure veggie oil or fryer grease, as a few people assumed. Biodiesel is created by chemically processing vegetable or animal oils (fats), including waste oils from restaurants, to create a product that chemically resembles petroleum diesel. In the US, almost all biodiesel is created from soybean oil. (Ethanol, on the other hand, is the biofuel of choice to blend with gasoline, and is typically created by fermenting corn or sugar (carbohydrates)). Biodiesel can be blended with or can completely replace petroleum diesel in any modern diesel engine without any modification. While it is more sensitive to the cold than petroleum diesel, and may require that the fuel filter be changed once or twice as it cleans out an old engine, many advocates claim that engines perform better, cleaner, and longer, partly due to biodiesel's high lubricity and solvent cleaning characteristics.

As a side note, in San Francisco we met up with the crew from Dartmouth's Big Green Bus, which is running straight vegetable oil (SVO) in the diesel engine of an old school bus. To do this, they needed to add a second fuel tank to the bus and route the (hot) coolant line through this oil tank (to heat the oil so it flows and combusts well). Their engine starts with normal diesel, but runs on oil once the oil in the tank is hot enough to flow through the fuel injectors. This crew had their own filtration equipment, so they were able to fuel up at Chinese and fast food restaurants all along the way. We found a more extreme in Ithaca, where we met a ferry operator who did not change anything with his engine or fuel lines, and has for years been blending up to 30% filtered oil from local restaurants into his diesel tank in the summer. Apparently the fuel injectors in ferry engines are much more forgiving than the narrow fuel injectors in road vehicles.

FUEL-FINDING LOGISTICS

Because biodiesel is still breaking into the market, we knew it would take some effort to consistently fill up our tank with B20; this is why our driver's company (Lamoille Valley Transportation) created a list of fueling stations for us to visit between our stops, using the National Biodiesel Board's online distributor map (though it's also possible to call 1-800-BIODIESEL to obtain the same information). One major consideration for us was that our vehicle was donated to us for the summer by Motor Coach Industries (MCI), so we had to take good care of it and be diligent with our fuel purchases. For this reason, we would only purchase fuel from merchants that can prove their product had been certified to ASTM standards. We would have liked the biodiesel to come from BQ-9000 (NBB's quality control system) certified producers, but that would have ruled out most of the stations in the country. In summary, we had a brand new diesel engine, and were afraid to ruin it with biodiesel made in someone's garage.

Because we'd be covering so much ground (on average 160 miles/day), and the bus's tank has a range of around 1400 miles, I assumed we wouldn't ever have trouble finding at least one station to re-fuel our baby along the way. I was wrong. A few states had less than a handful of fuel stations carrying biodiesel, and among the stations that seemed legitimate based on LVT's list or my own research, we ran into the following problems:

- A few of the stations were out of the way or didn't fit our schedule.
- One station had a \$50 purchase limit and cut off Joel's credit card after filling up just a fifth of the tank (despite my call ahead to ensure we'd have no obstacles).

- One station required that we follow their employee a mile down the road to an alternative fueling area for biodiesel. Had we not requested that we prepay for 200 gallons (since we were running late for dinner), we would have needed to drive all the way back to their main office to pay for the fuel.
- Another station that I found on the NBB's website was not even selling biodiesel at the location listed on the map!

Fuel-Finding Process

When we needed to find a place to fuel up on the road, I would typically follow the following steps:

1. Visit the DOE's alternative fuel finder website [<http://www.eere.energy.gov/afdc/infrastructure/locator.html>], which is more user-friendly than the NBB website [nbb.org].
2. After finding a station, I would check to see if the station was a member of the NBB, which improved my confidence that the station existed and was reputable.
3. I would call them to confirm that they are open to the public, that they do sell B20, that they will be open when we'll be driving by, and that their credit card machines will let us purchase approximately 200 gallons.

There were only two situations on the whole trip when we were stuck with a nearly empty tank, and were prepared to ditch our loyalty to B20 in order to ensure the bus would continue moving. Both experiences happened consecutively as we were leaving Yosemite (far from any public stations listed on either website). Luckily, on our second desperate fuel-up stop we pulled into a Chevron that coincidentally sold biodiesel, so we ended up only putting a few gallons of regular diesel into the tank on one occasion throughout the summer.

By the end of the trip, we had only fueled up at half of the originally planned fueling stations. Please note: this more often resulted from pleasant surprises than disappointments. We stumbled across a handful of biodiesel-carrying fueling stations along the way that were not listed on either of these websites. The SeQuential station in Oregon was the most pleasant surprise of the trip: in addition to carrying biodiesel and E85, they had redeveloped an old contaminated gas station, they use bioswales to treat stormwater, they have a green roof and solar panels and sell local organic food in their store – definitely not an old-fashioned gas station!

ECONOMIC EVALUATION

Thanks to various tax incentives (ex. a \$1/gallon federal blender's credit), and recently high crude oil prices, the cost of B20 throughout the summer (our average \$2.98) was not much different than the cost of petroleum diesel. This may come as a surprise, given that the production costs in 2007 for biodiesel was \$2.44, while conventional petroleum diesel only cost \$0.78 per gallon (Energy Information Administration).

Below is a simplified table showing the costs of using biodiesel throughout the summer, generalized for the whole country. A side by side comparison is also made to the estimated cost for using other alternative and conventional fuels for a similar cross country road trip. To create this table, several assumptions were made, and some variables ignored (see below the table).

LBT Alternative Fuels Comparison: Fuel Consumption and Cost Estimates									
Vehicle	# passengers	Fuel	Energy density vs. diesel	\$/gal	Miles	Gallons (actual)	Total Cost	Gal/ Person	\$/ Person
Motor Coach (6 mpg)	13	B20	0.98	\$2.96	12060	2050.7	\$6,070	158	\$467
	13	Petro Diesel	1.00	\$2.96	12000	2000.0	\$5,920	154	\$455
	13	B99	0.91	\$3.27	12060	2206.7	\$7,216	170	\$555
Car (20 mpg)	4	E85	0.63	\$2.63	12060	951.5	\$2,502	238	\$626
	4	Gas	0.90	\$3.03	12000	669.3	\$2,028	167	\$507

Assumptions:

- **VEHICLE AND FUEL:** Alternative fuels to B20 would obviously include using petroleum diesel or B100/B99 (note: B99 was more prevalent due to incentives for “blenders”). While the number of passengers did vary, the trip was designed to transport 13 Udall riders across the country in a motor coach with a fuel efficiency of at least 6 mpg. Another realistic option to traveling by bus may have been riding in a car with three friends. A typical car may get 20 mpg and would run on gasoline or E85.
 - Note: While the idea of running a retrofitted school bus on vegetable oil was often discussed, too little is known about the costs, reliability, and emissions of SVO to have been truly considered in this evaluation.
- **FUEL COSTS:** The sample group of fueling stations we used was a small fraction of the biodiesel vendors throughout the country, though the trip average of \$2.98 compared closely to the July national average of \$2.96. National averages will be more appropriate to present comparisons for the general public, so the DOE’s July 2007 summary of national fuel prices was used for this evaluation.
- **MILES DRIVEN:** While the duration of the trip was about 9,000 miles for the Udall riders (see Appendix), the miles associated with the Legacy Bus Tour (or any cross-country trip) should at least include the miles associated with returning the vehicle to its original location. For this reason, the total vehicle driving distance is loosely estimated to be 12,000 miles.
- **CONVENIENCE FACTOR:** We planned almost all of our fuel stops, and because many of these distributors were not directly along our path, I estimate that purchasing biodiesel added 0.5% of our total mileage to the trip. A similar factor could be expected for using E85 in a car.

Ignored Economic Impacts:

- However, the external advantages that have not been considered include supporting US farmers, increasing energy independence, and reducing the adverse air quality (and therefore health care) impacts associated with transportation.
- The cost of the bus’s custom manufacturing, operation (including a hired driver) and maintenance were ignored in this evaluation.
- Public transit, taxi and limo rides associated with the LBT were ignored in estimating total fuel consumption.

ENVIRONMENTAL EVALUATION

Emissions Summary

My main goal, and one of the most interesting aspects of the Legacy Bus Tour, was to monitor actual (particulate matter) emissions leaving the tailpipe as we drove across the country. Unfortunately, due to mechanical complications, it became impossible to carry out this task. As a result, I am only able to present data that has already been collected. I have selected and pasted below a table from one of NREL's Milestone Reports, which shows how B20 successfully lowers the emissions of most of the major pollutants¹ in a variety of diesel vehicles.

Table 23. Average Percent Change in Emissions and Fuel Economy for All Vehicles Tested.

Vehicle	Cycle	NO _x % Change	PM % Change	CO % Change	THC % Change	Fuel Econ % Change
Transit Bus #1	CSHVC	-5.8	-17.4	-26.8	-28.3	-2.2
Transit Bus #2	CSHVC	-3.9	-33.0	-20.3	-28.0	-2.0
Transit Bus #3 (Average)	CSHVC	-3.2	-18.9	-15.3	-25.1	-1.9
Freightliner Class 8	CSHVC	2.1	-19.4	-10.7	-15.2	-1.5
	Freeway	3.6	-26.2	-6.9	-16.0	-1.6
Motor Coach	CSHVC	2.8	-28.1	-22.3	-14.5	-1.3
	UDDS	3.4	-30.0	-19.2	-3.4	-0.6
International Class 8	CILCCmod	-0.1	-27.2	-15.3	-16.8	-2.3
	Freeway	2.3	-34.7	-14.5	-12.4	-0.5
Green Diesel School Bus	CSHVC	-0.8	28.0	-15.9	35.2	-2.0
	RUCSBC	2.3	15.6	-41.7	-7.0	-0.8
Conventional School Bus	CSHVC	-0.7	2.5	9.5	-1.1	-1.1
	RUCSBC	6.2	-24.0	-22.6	-19.6	-0.3
Overall Average % Difference		0.6	-16.4	-17.1	-11.6	-1.4
95% Confidence Interval		±1.8	±10	±6.1	±8.6	±0.36

The quote from this report (pasted below) highlights how modern technologies, such as those employed in our new Caterpillar engine (particulate filter and clean exhaust recirculation), can often lead to “green” impacts that would be unachievable using an old beat-up vehicle (regardless of the fuel choice).

On average B20 caused PM and CO emissions to be reduced by 16% to 17% and HC emissions to be reduced by 12% relative to petroleum diesel. Emissions of these three pollutants nearly always went down, the exception being a vehicle equipped with a diesel

¹ Note: As part of obtaining Green Coach Certification, carbon credits were purchased to offset carbon dioxide emissions from the bus; however, it is important to consider that pollution offsets do not currently exist for these other (local) air pollutants.

particle filter that showed very low emissions of PM, CO, and HC; and there was no significant change in emissions for blending of B20. The NO_x impact of B20 varied with engine/vehicle technology and test cycle ranging from -5.8% to +6.2%.

Miscellaneous Environmental Impacts

It is important to remember that the environmental impacts of the Udall Legacy Bus Tour extend well beyond fuel consumption and engine emissions. Almost any activity related to the legacy of Morris K. Udall is likely to come with a strong benefit for the environment. However, as a minimum attempt to capture the indirect environmental impacts of the summer bus tour, I wanted to figure out if riding on the bus resulted in a greater carbon footprint for the riders than would have otherwise occurred (during the summer and afterwards). To do this, I asked my fellow riders to estimate what their alternative summer plans would have included (had they not been on the bus), and how the LBT may have influenced their future traveling plans. My questions and the riders' responses to these questions are summarized below:

1. Had you not been on the bus this summer, roughly how much would you be driving each week, including weekends?
 - Three of the riders would have expected to exclusively take public transit all summer.
 - The other eight riders would have expected to drive anywhere between 250 and 4200 miles, with an average of 1800 miles (which would have required approximately 90 gallons of fuel, assuming the rider independently drove a 20mpg car).
2. Did you not go on any big trips over the summer (ex. a wedding or a trip to New Zealand) because of the LBT?
 - Five riders said they would not have expected to go on any big trips.
 - The other six riders would have flown once or twice, for an average of 4900 miles total (which may require approximately 60 gallons of fuel, according to some estimates that airplanes get the equivalent of 80 passenger-miles/gallon).
3. Did this trip make you more or less interested in doing another cross-country trip or other travel in the future (ex. did the LBT satisfy a lifelong urge to drive cross-country)?
 - Five riders believed the trip made them less likely to travel.
 - Two riders believed the trip made them more likely to travel in the future.
 - Four riders did not feel more or less inclined to travel in the future as a result of the LBT.

Based on these responses, the typical rider's travel plans would have required less than 150 gallons of fuel this summer, which is less than the LBT per-rider average fuel consumption of 160 gallons (as shown in the LBT Fuels Comparison Table). While interesting to think

about, the LBT's influence on the riders' future travel (or professional/activist) plans is too difficult to attempt to quantify.

CONCLUSION

As expected, it is extremely difficult to draw a box around the environmental (and economical) impacts of an activity such as the Legacy Bus Tour. Even finding literature to help estimate the emissions from our bus, or an alternative vehicle (such as a "veggie bus"), proved to be more difficult than expected. Despite these shortcomings (evident by some of the simple assumptions and unanswered questions listed in this paper), it is safe to say that the Udall Legacy Bus Tour was among the cleanest and greenest bus tours on the road this summer. It is also important to remember that scientists, economists, engineers and politicians will continue to search for energy technologies that seem to be "win-wins" like biodiesel, and that purchasing fuels such as biodiesel is only one piece of the puzzle, to be coupled with improving the overall resource efficiency of our lifestyle.

As any of the riders would have said during the summer, promoting biodiesel was not the purpose of the tour. However, promoting alternative energies and clean technologies, and practicing what we preach, are characteristic of Mo' Udall's legacy of environmental stewardship. Buying B20 was symbolic of Mo's legacy as much as were many of our other activities this summer, such as supporting local and organic farmers, picking up litter, cleaning up park trails, and educating the public about Native American issues or the National Parks. Regardless of the direct or indirect environmental impacts associated with this 54-day road trip, I hope and believe that the adverse environmental impacts associated with the LBT (i.e. flying, traveling on the bus, staying in hotels, purchasing over-packaged food, etc.) will be completely negated by the positive repercussions the tour had on the public and Udall community for years to come.

KEY REFERENCES / USEFUL WEB-PAGES

<http://www.eere.energy.gov/afdc/infrastructure/locator.html>

- Department of Energy (DOE) – Energy Efficiency & Renewable Energy (EERE) - Alternative Fuel Finder

<http://nbb.org/buyingbiodiesel/distributors/>

- National Biodiesel Board (NBB) - Biodiesel Distributor's Map

<http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40554.pdf>

- National Renewable Energy Lab (NREL) - Milestone Report on biodiesel emissions

http://www.eere.energy.gov/afdc/resources/pricereport/pdfs/afpr_jul07.pdf

- DOE - EERE - Alternative Fuels Price Report

<http://www.eia.doe.gov/emeu/plugs/plbiodsl.html>

- DOE - Energy Information Administration (EIA) - Energy Production cost estimates for biodiesel & diesel

APPENDIX A - FUEL LOGS

Udall Legacy Bus Tour
Fuel Purchase Logs - Summer 2007

20-Aug-07

Date	State	Company	Gallons	Fuel	Cost	listed price
11-Jun	PA	Pilot	30.42	B20	90	\$ 2.96
11-Jun	PA	Pilot	35.186	B20	102.01	\$ 2.90
12-Jun	PA	S&B Auto	166.72	B20	500	\$ 3.00
12-Jun	PA	S&B Auto	23.34	B20	70	\$ 3.00
17-Jun	ME	Frontier	170.2	B20	510	\$ 3.00
20-Jun	VT	C.O. Co	84.9	B20		
26-Jun	OH	Delaware	16.67	B20	50	\$ 3.00
26-Jun	OH	Delaware	16.67	B20	50	\$ 3.00
26-Jun	OH	Delaware	16.67	B20	50	\$ 3.00
		Chicago				
29-Jun	IL	Speedway	100.04	B20	310.03	\$ 3.10
2-Jul	TN	Daisy's	165.57	B20	453.51	\$ 2.74
5-Jul	LA	(NOLA)	53.58	B20	150	\$ 2.80
8-Jul	KS	(Wichita)	193.5	B20	580.5	\$ 3.00
13-Jul	CO	Commerce City	153.2	B20	479.36	\$ 3.13
19-Jul	MT		24.67	B20	74	\$ 3.00
19-Jul	MT		130.87	B20	387.26	\$ 2.96
27-Jul	OR	SeQuential	65.14	B20	200	\$ 3.07
27-Jul	OR	SeQuential	86.84	B20	266.59	\$ 3.07
31-Jul	CA	Chevron	18.29		75	\$ 4.10
31-Jul	CA	Chevron	31.246	B100		
31-Jul	CA	Chevron	174.743	ULSD	552.01	\$ 3.16
			1758.465		4950.27	2.98

Note: Highlighted cells contain estimates or uncertainty.

APPENDIX B - ODOMETER (MILEAGE) LOGS

Udall Legacy Bus Tour
Odometer Logs - Summer 2007

20-Aug-07

Date	Miles	Date	Miles
10-Jun	0		
11-Jun	455	5-Jul	73
12-Jun	167	6-Jul	413
13-Jun	162	7-Jul	387
14-Jun	215	8-Jul	11
15-Jun	27	9-Jul	344
16-Jun	241	10-Jul	14
17-Jun	295	11-Jul	521
18-Jun	0	12-Jul	0
19-Jun	205	13-Jul	180
20-Jun	331	14-Jul	494
21-Jun	149	15-Jul	0
22-Jun	330	16-Jul	87
23-Jun	26	17-Jul	120
24-Jun	260	18-Jul	307
25-Jun	33	19-Jul	0
26-Jun	610	20-Jul	496
27-Jun	135	21-Jul	25
28-Jun	0	22-Jul	0
29-Jun	65	23-Jul	185
30-Jun	472	24-Jul	83
1-Jul	71	25-Jul	347
2-Jul	534	26-Jul	63
3-Jul	27	27-Jul	336
4-Jul	0	28-Jul	26
		TOTAL	9322

APPENDIX C - SURVEY RESULTS

Udall Legacy Bus Tour

20-Aug-07

Survey Results - Alternative Summer Travel Plans

	A	B	C	D	E	F	G	H	I	J	K	
Driving miles (total)	250	2000	400	800	3000	transit	transit	transit	4200	3000		500
Appx gallons (miles/20)	12.5	100	20	40					210	150		25
Otherwise - big trips (flight miles)?	No	No	6000	No	6000	2500	1600	6000	No	7500	No	
More or less likely to travel now?	Less	-	-	More	Less	Less	-	-	More	Less	Less	